(12) UK Patent Application (19) GB (11) 2 356 708 (13) A

(43) Date of A Publication 30.05.2001

(21) Application No 9928008.3

(22) Date of Filing 27.11.1999

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(51) INT CL[7]
G01N 33/00 27/416

(52) UK CL (Edition S)
G1N NBKT N25A1 N25DX
U1S S1502

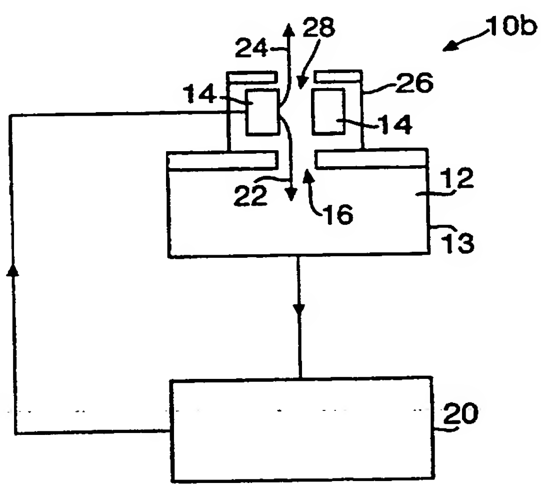
(56) Documents Cited
GB 2313198 A WO 99/24826 A WO 99/17110 A
WO 98/25139 A DE 004012466 A US 5046028 A
US 4267030 A

(58) Field of Search
UK CL (Edition S) G1N NACJ NBKT NCGB
INT CL[7] G01N 27/416 33/00
ONLINE: EPODOC, JAPIO, WPI

(54) Abstract Title
Sensor system with self-test facility

(57) The sensor system for sensing, for example, carbon monoxide includes a housing 13 containing a gas sensor 12, the housing having an aperture 16 formed therein so that gas can pass to the sensor; test gas means 14 for providing a test gas which is used to verify that the sensor is functioning; and control means 20 for analysing the response of the sensor to at least the test gas. The control means is used to analyse the response of the sensor so that generation of the test gas can be regulated in order to provide a system with improved self -test capability. In order to achieve this, the sensor system also includes various sensors such as an air speed sensor which measures the speed of a gas in the vicinity of the sensor and a temperature sensor. The invention can be applied to other self test systems such as smoke or other particulate detectors by generation of smoke or an aerosol, or ion-sensitive electrodes by local release of ions in solution.

Fig.1b.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date but within the period prescribed by Rule 25(1) of the Patents Rules 1995.

Fig.1a.

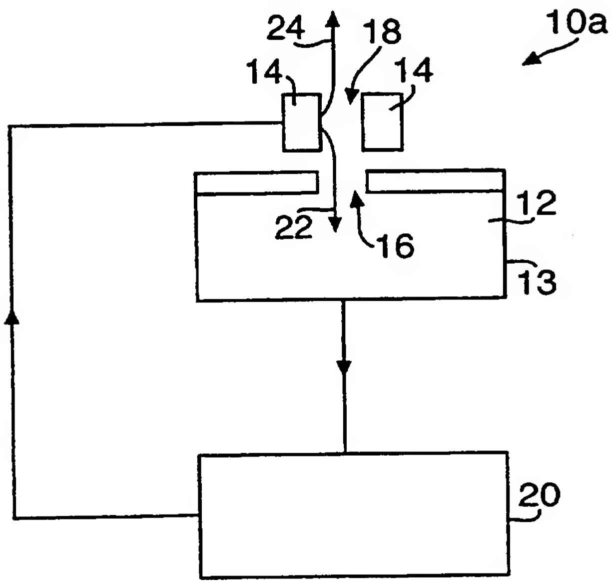


Fig.1b.

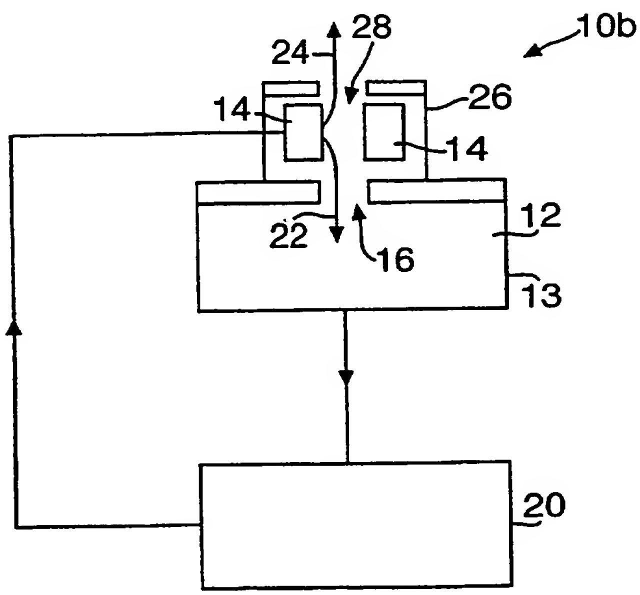


Fig.2a.

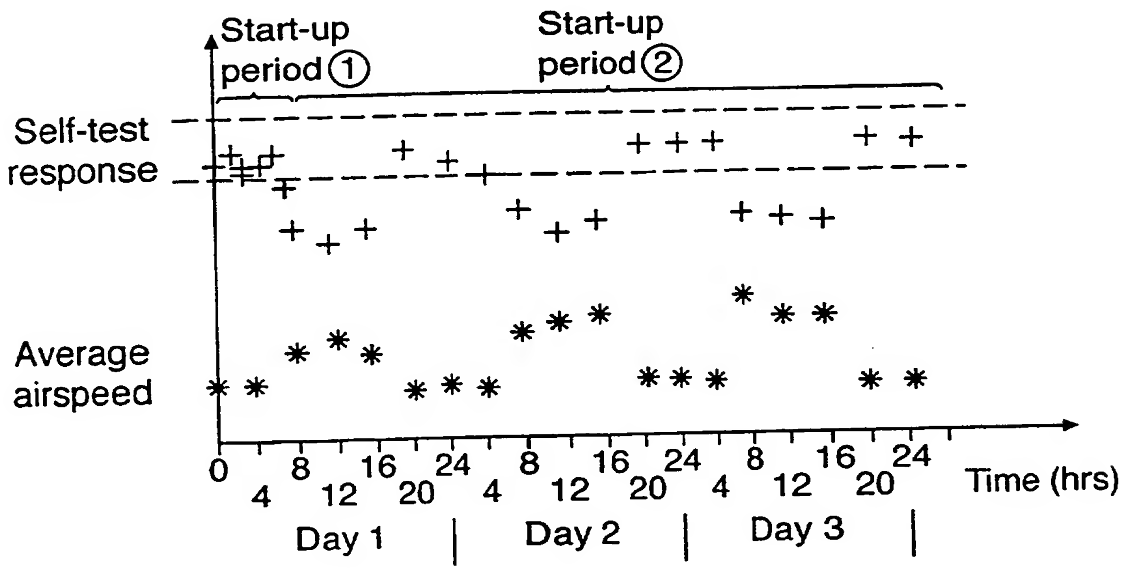

Start-up
period 1
Start-up
period 2
Self-test
response
Average
airspeed
0
4
8
12
16
20
24
4
8
12
16
20
24
4
8
12
16
20
24
Time (hrs)
Day 1
Day 2
Day 3

Fig.2b.

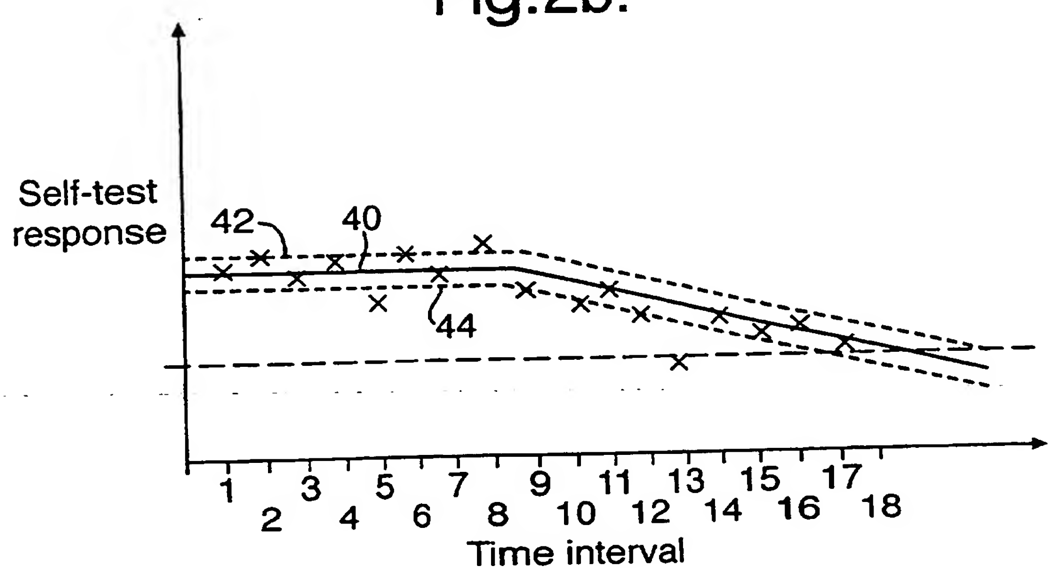

Self-test
response
42
40
44
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Time interval

Fig.3.

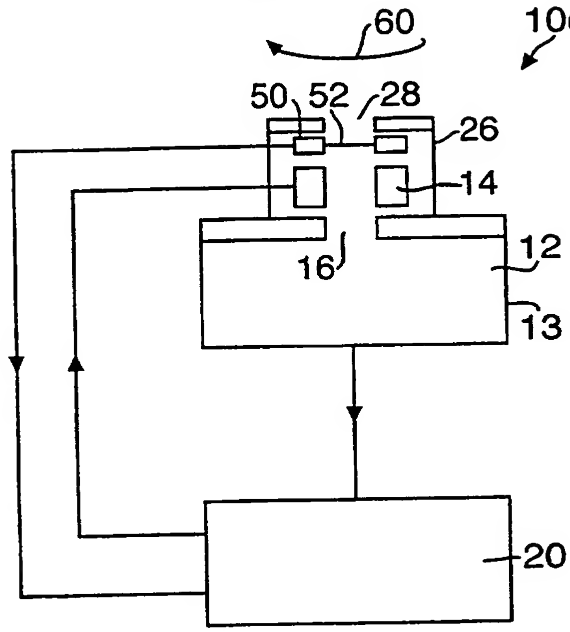


Fig.4a.

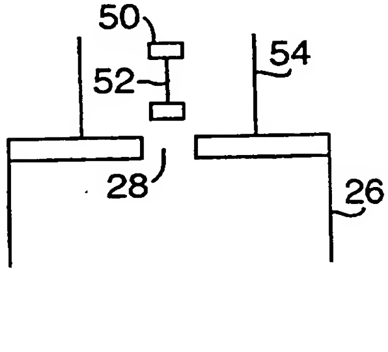
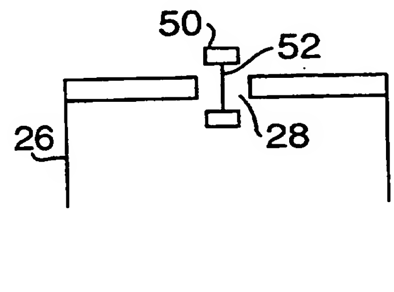


Fig.4b.



INTELLIGENT SENSOR SYSTEM

The present invention relates to an intelligent sensor system. It relates particularly, but not exclusively, to an intelligent sensor system for sensing carbon monoxide gas.

Conventional electrochemical gas sensors operate by oxidising a gas at a sensing electrode, thereby generating a current. The rate of arrival of the gas at the sensing electrode is determined by a diffusion barrier, and the rate at which the electrode can oxidise the gas is arranged to be very much greater than the rate at which gas diffuses through the barrier. Therefore the rate of oxidation, and hence the current, is controlled solely by diffusion, and this is a known value for a given gas concentration when the sensor is manufactured. If the activity of the sensing electrode decreases over time (through poisoning for example) then the current eventually becomes limited by the lowered oxidation rate at the electrode, and the sensitivity of the sensor falls. There is then no way of telling from the cell output whether the gas concentration is low, or if the gas concentration is high and the sensing electrode has lost activity.

In-situ self-testing of gas sensors may be achieved by a remotely-controlled supply of test gas in or near the sensor, e.g., by electrolysis of water in an electrolyte to generate hydrogen for calibration of, for example, carbon monoxide sensors. If the test gas is delivered inside the sensor (i.e. inside the diffusion barrier that controls the sensor response), as described in US Patent No. US 5668302 (City Technology / DeJaray) and UK Patent Application No. GB 2,254,696 A (Thorn-EMI), then the test gas diffuses from the test gas delivery site to the sensing electrode where it is detected, and operation of the sensor confirmed.

If test gas is delivered outside the sensor, as disclosed in UK Patent No. GB 1,552,538 (Bayer), the test gas then diffuses through the diffusion barrier into the sensor in order to be detected. **The self-test response depends on the concentration of test gas created outside the cell.** Failure of the sensor might be sudden and catastrophic, e.g., by obstruction or blockage of the inlet (caused by cleaning, painting or physical obstruction). On the other hand, failure may be gradual, such as might occur through poisoning of the electrodes by contaminants, by decay of electrode activity towards the end of the sensor's

life, or by gradual blockage of the barrier by insects or dust. In these cases, response to test gas will fall gradually with time, and when it falls below a given threshold the sensor will be deemed to have failed and will need to be replaced.

Self-test of a sensor using gas delivered between a diffusion barrier and the sensing electrode is not a good measure of the calibration of the sensor, as the response of the sensor to the test gas **of the sensor electrode without diffusion limitation is unlikely to be reproducible from Sensor to Sensor**. In addition, failure of the sensor through blockage of the diffusion **barrier** will not be detected using this method. Delivery of gas outside the main diffusion barrier allows both self-calibration and testing for barrier blockages, but a greater amount of gas needs to be produced in order to compensate for loss of the test gas to the surroundings. These losses will be variable, depending on exterior air currents from, for example, ventilation systems or open windows, and also on temperature changes in the air currents – factors which are likely to show a strong cyclical variation. In practice, the amount of gas that is lost to the surroundings is a significant factor in the self-test process.

Loss of the test gas can be reduced by placing a second barrier between the test gas source and the outside world, as described in the applicant's co-pending International Patent Application No. WO 9825139 A1. However, in order to maintain the advantage of testing for blockage of the main diffusion barrier, this second barrier needs to have a higher permeability than the main diffusion barrier. That is, the second diffusion barrier must not be likely to be a source of blockage itself.

An aim of the present invention is to provide a sensor with improved self-test capability. Another aim of the invention is to provide an intelligent sensor system.

According to a first aspect of the invention there is provided an intelligent sensor system including: a) a housing containing at least a sensor including a sensing electrode, the housing having at least one inlet for gas so that gas can pass to the sensing electrode; b) test gas means for providing a test gas which is used to verify that the sensor is functioning; and c) control means for analysing the response of the sensor to at least the test gas.

The inlet may be a diffusion barrier which limits the amount of gas reaching the sensor, or an aperture in the housing. **If the Sensor includes a difficusion barrier,** preferably the test gas means is located on the opposite side of the diffusion barrier to the sensor, so that the test gas passes through the diffusion barrier. Most preferably the test gas means is located adjacent the diffusion barrier so that the test gas is delivered as closely as possible to the diffusion barrier in order that a minimal amount of test gas escapes from the housing into the atmosphere.

The housing may define two chambers, the chambers being separated from one another by the diffusion barrier. Preferably the first chamber contains a sensor, and the second chamber the test gas means. The second chamber preferably has an inlet in order to permit gas from the atmosphere to flow to the sensor. The second chamber may also contain an air speed sensor for measuring the speed of the air in the vicinity of the sensor.

The control means preferably also analyses the sensor response to gas from the atmosphere. It may also control the generation of test gas, i.e., the amount of gas generated, and the times at which the gas is generated. Preferably the control means analyses the air speed measurements provided by the air speed sensor.

Preferably the controller logs the sensor responses against time, and analyses the responses for patterns. Additional sensors are preferably provided for variables which might affect response, such as air flow and temperature, or for variables which might give secondary information on whether interference from air flow is likely, such as movement sensors for building occupancy or light sensors, and patterns in responses of these sensors could be monitored also. Air disturbance is likely to be greatest when the building is occupied, usually during the day, and so self-test is likely to be best done at night. A system which operates self-test at a fixed time, e.g. 2 a.m., might overcome most problems. When installed, the sensor might be set up to run self-test at a given time. However, a system which logs patterns in the environment of the sensor and then makes a decision when to self-test, is more robust. For instance, the sensor might be installed in a building with a night shift occupancy and hence **the self-test response** might vary with day of the week.

Preferably the sensor system runs self-test more frequently soon after installation when the sensor is known to be in operational condition, thereby learning what the pattern of test

response is for the sensor in its particular location. The expected range of self-test responses would then be known and an optimum time chosen. Later tests are preferably run much less frequently. Responses within the expected range would not in themselves be a cause for warning of failure. However, the system may register a series of responses near the lower end of the range and test at different times for a period, to check that air flow conditions near the sensor have not changed. Sudden results out of range advantageously trigger a re-test, to check that the sensor had not been physically covered or blocked, or the electrode catastrophically poisoned.

Additionally, in order to conserve power or reserves of material for gas generation, the self-test process may be run using a variable amount of gas. Regular checks that the sensor is operating at all may be made with smaller amounts of gas, with calibrations using larger amounts at longer intervals. The amount of gas used is preferably set by the control system in the light of information from its clock or ancillary sensors, so that self-calibration is only attempted under optimum conditions. Also, the calibration may be done in two stages: response to an initial small amount of gas could be observed, and if it is great enough (which implies that losses to air currents are low at that time), then self-calibration could be run.

Such a system would necessarily increase the power requirement over a system where a single self-test operation is carried out at intervals. However, the invention would be much less prone to false results, and is almost a necessity if a self-test sensor with test gas delivery outside the main response-controlling diffusion barrier is to be used in buildings with uncontrolled air flow patterns. It could easily be incorporated into the micro-controller envisaged in present gas alarm circuitry.

The sensor may be, for example, a gas sensor, an ion sensor or a smoke sensor **with appropriate modification to the source of test substrates**.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying Figures, in which:-

Figure 1a shows a cross-sectional view of a sensor system;

Figure 1b shows a cross-sectional view of a sensor system having a second diffusion barrier;

Figure 2a shows a graph of sensor response and average air-speed, against time;

Figure 2b shows a graph of sensor response over time;

Figure 3 shows a cross-section of a sensor system having a second diffusion barrier and an air-speed sensor; and

Figures 4a and 4b show a cross-sectional view of the positioning of air-speed sensors.

Referring now to Figure 1, there is shown a schematic representation of a sensor system (10a) with self-test capability. System (10a) includes a gas sensor (12) disposed within a housing (13). The housing has an aperture (16) in its upper surface which permits gas (both test gas and gas from the environment) to enter the sensor (12). Aperture (16) is frequently used as a diffusion barrier in order to control the response of the sensor (12) - such diffusion controlled sensors are well known in the art.

The sensor system (10a) also shows a test gas delivery device (14) mounted above the aperture (16). The test gas delivery device (14) generates gas by, for example, electrolysis of electrolyte, or by release of gas from a storage means. Gas from the atmosphere to be sensed flows past test gas delivery device (14) and enters the system via diffusion through aperture (16) (shown by arrow (18)). Sensor (12) is connected to a controller (20) which in this case in located beneath housing (13). The controller (20) interprets the sensor output, communicates with other systems, and sounds an alarm if, and when, appropriate. Controller (20) also triggers release of test gas from delivery device (14). Test gas from the test gas delivery device (14) either enters the housing (13) via aperture (16) (shown by arrow (22)), or it escapes to the atmosphere (shown by arrow (24)). The ratio of the amount of test gas sensed by the sensor (22) to the amount of test gas which escapes into the surrounding atmosphere (24), determines the self-test response for a given rate of delivery of test gas.

The amount of test gas which escapes to the atmosphere increases when air currents are present. Figure 1b shows a sensor system (10b) in which an additional housing portion (26)

having a further aperture (28) is provided in order to enclose the test gas delivery device (14). This limits the amount of self-test gas escaping to the atmosphere and also the effect of air currents. The shape and size of aperture (28) determines the extent to which this is achieved. For instance, aperture (28) may comprise holes of defined cross section and length, tortuous passages in the bulk of a material or defined by components of the system, or simple meshes, grilles or louvres. The ratio of the diffusion limiting effect of the two apertures (16) and (28) is a feature of the design of the sensor system (10b).

The controller (20) sends control signals to the test gas delivery system (14), and has an internal clock which measures either real or elapsed time. Initially the controller runs the self-test function at frequent intervals of the order of once every two hours, and logs the response against time. Figure 2a illustrates the response of sensor system soon after it has been installed, and the average airspeed in the vicinity of the system. The intervals can be varied to suit the environment in which the sensor system (10) operates, and the required power consumption of the system.

In general, when the air speed in the vicinity of the sensor system is high, the output response of the sensor will be low. The controller (20) analyses the sensor response for short term variance (i.e., a convolution of short term variation in air speed, variation in sensor response and any variation in function of the gas delivery device), and for longer term variations which represent cyclical variation in air speed. Long term variations in the sensor response are likely to be on the scale of days. Cyclical variations tend to represent changes in building use over time. By making self-test measurements at a higher rate during an initial period after installation, the controller (20) is able to discern these cycles and the variance in self-test readings taken at given times during the day.

The sensor system can be started at a time when air currents are known to be absent in the building, if this information is available. This speeds up the start-up process and reduces the amount of power and/or test gas used in the initial data collection period. Two (or more) initial periods can be defined, with greater and then lesser frequency of readings, as shown in the graph of Figure 2a. The first start-up period might be under user control and the second then run by the system to consolidate its operating parameters. However, the

system is intended to be able to start itself up and learn the parameters of the environment where it is installed without intervention from an operator.

Figure 2b shows a schematic graph of the responses of the sensor system (10) over time. After an initial testing period, the controller (20) runs subsequent tests at the particular time of day when the sensor response was on average highest in the initial testing period. The variation information obtained by the controller allows upper (42) and lower (44) limits to be set about a mean line (40) fitted by the controller to the sensor readings. Outside the upper and lower limits readings are rejected as being likely to be spurious. Such spurious readings may be caused by, for example, temporary changes in local air speed which may be caused by an open window.

The controller (20) runs a continuous averaging process on the sensor readings and detects trends in the data. These trends can be seasonal, related to temperature and humidity for instance. Such trends may be detected more readily, and the validity of individual readings can be enhanced by the information obtained on expected short terms variations in the sensor response. Eventually, in the case of sensor failure, the downward trend in response intersects an alarm point and the sensor will be deemed to have failed. The algorithms used for analysis in the controller are standard algorithms known in statistical analysis.

Figure 3 shows a sensor system (10c) which includes an air speed sensor (50) located within the second housing (26), between aperture (28) and the test gas delivery device (14). The air speed sensor (50) is located close to the aperture (28) in order to accurately monitor the conditions affecting gas movement through the aperture. Air speed information is fed to the controller (20), and is used to interpret the self-test response. Air speed is logged against time, and the self-test function run at times when air speed is, on average, lowest. If air speed exceeds the mean air speed by a certain amount, then the self-test can be postponed to save power.

The air speed sensor (50) is a hot-wire type, in which the power needed to maintain a certain temperature of the wire depends on the air speed past the wire. Such air speed sensors have the advantage that they can have isotropic response in two dimensions. It is a matter of design choice whether the wire is oriented perpendicular to the axis of the

aperture (28), or parallel to it. In either case, the air speed sensor is operated intermittently in order to save power.

Referring now to Figure 4, there are shown schematic representations of possible positions of the air speed sensor (50) in relation to the housing (26). In Figure 4a it is placed outside the gas delivery device housing (26), and a wind shield (54) is placed around the air speed sensor (50) to reduce effect of air currents. Figure 4b shows an air speed sensor (50) disposed in the aperture (28) itself. This has the advantage of precisely measuring the conditions that self-test gas experiences on exiting the housing (26), and sensed gas experiences on entering the housing (26).

Other types of air speed sensor (such as a heated spherical thermistor) can be also used in the invention, subject to their being sensitive to air movement in all directions. Variation may be made to the aforementioned embodiment without departing from the scope of the invention. For example, the invention may be applied to any form of gas sensor, including heated catalytic sensors, infrared sensors and electrochemical sensors, or to any sensor **for other substances** with a self-test function in which a substance released to the surrounds of the sensor is used to test the response. Examples of **such** self-test sensors include ion-sensitive electrodes where self-test might involve local release of ions in solution and varying flow patterns in the solution cause variation in the readings, and also smoke or other particulate detectors, where smoke or aerosol might be generated and dissipated by air currents.

Claims

1. An intelligent sensor system (10) including: a) a housing (13) containing at least a gas sensor (12), the housing having at least one aperture (16) so that gas can pass to the sensor; b) test gas means (14) for providing a test gas which is used to verify that the sensor (12) is functioning; and c) control means (20) for analysing the response of the sensor to at least the test gas.
2. An intelligent sensor system (10) according to claim 1 wherein the control means (20), in use, controls the generation of the test gas.
3. An intelligent sensor system (10) according to claim 2 further including an air speed sensor (50) which, in use, measures the speed of a gas in the vicinity of the sensor (12).
4. An intelligent sensor system (10) according to claim 3 further including a temperature sensor.
5. An intelligent sensor system (10) substantially as described herein with reference to the drawings.

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Application No: GB 9928008.3
Claims searched: 1 - 5

Examiner: Dave Mobbs
Date of search: 21 March 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G1N NACJ, NBKT, NCGB.

Int Cl (Ed.7): G01N 27/416, 33/00.

Other: ONLINE: EPODOC, JAPIO, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2,313,198 A	(DRÄGERWERK AKTIENGESELLSCHAFT)	1.
X	WO 99/24826 A	(CENTRAL RESEARCH LABORATORIES LIMITED)	1.
X	WO 99/17110 A	(ANALYTICAL TECHNOLOGY, INC.) - see particularly page 6 paragraph 2.	1, 2.
X	WO 98/25139 A	(CENTRAL RESEARCH LABORATORIES LIMITED)	1.
X	US 5,046,028 A	(BRYAN & CUSHMAN)	1, 2. Cited in view of statements on page 8 lines 15-22.
X	US 4,267,030	(BAYER AKTIENGESELLSCHAFT) - see claim 1 and column 5 lines 54 - 55.	1, 2.
X	DE 40 12 466 A	(RUMP ELEKTRONIK TECH.)	1. Cited in view of statements on page 8 lines 15-22.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		